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Topliss et al.

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(54) **MIXED REALITY SYSTEM**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)

(72) Inventors: **Richard J. Topliss**, Campbell, CA (US); **Thomas M. Gregory**, Cambridge (GB); **Paul J. Gelsinger-Austin**, Santa Clara, CA (US); **Richard H. Tsai**, Cupertino, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

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H04N 7/18 (2006.01)
H04N 13/344 (2018.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04N 13/344*** (2018.05); ***G02B 27/0172*** (2013.01); ***H04N 9/3129*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H04N 7/18; H04N 13/344; H04N 13/383; H04N 13/398; H04N 9/3129;
(Continued)

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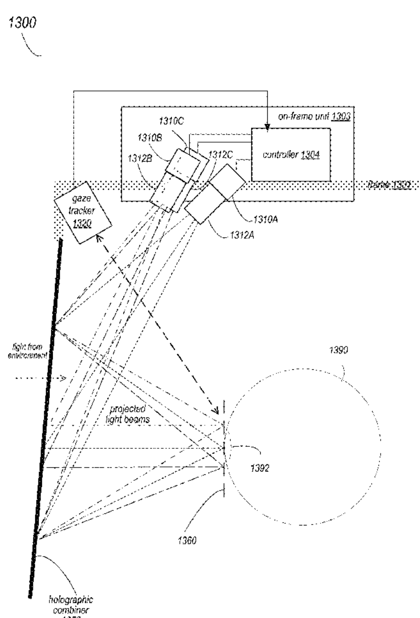
Primary Examiner — Trang U Tran
(74) *Attorney, Agent, or Firm* — Robert C. Kowert; Kowert, Hood, Munyon, Rankin & Goetzel, P.C.

(57) **ABSTRACT**

A mixed reality direct retinal projector system that may include a headset that uses a reflective holographic combiner to direct light from a light engine into an eye box corresponding to a user's eye. The light engine may include light sources coupled to projectors that independently project light to the holographic combiner from different projection points. The light sources may be in a unit separate from the headset that may be carried on a user's hip, or otherwise carried or worn separately from the headset. Each projector may include a collimating and focusing element, an active focusing element, and a two-axis scanning mirror to project light from a respective light source to the holographic combiner. The holographic combiner may be recorded with a series of point to point holograms; each projector interacts with multiple holograms to project light onto multiple locations in the eye box.

22 Claims, 15 Drawing Sheets



(51) **Int. Cl.**

H04N 13/383	(2018.01)
H04N 13/398	(2018.01)
H04N 9/31	(2006.01)
G02B 27/01	(2006.01)

(52) **U.S. Cl.**
CPC ***H04N 9/3161*** (2013.01); ***H04N 13/383*** (2018.05); ***H04N 13/398*** (2018.05); *G02B 2027/0112* (2013.01); *G02B 2027/0134* (2013.01); *G02B 2027/0174* (2013.01)

(58) **Field of Classification Search**
CPC H04N 9/3161; G02B 27/0172; G02B 2027/0112; G02B 2027/0134; G02B 2027/0174
USPC 348/77
See application file for complete search history.

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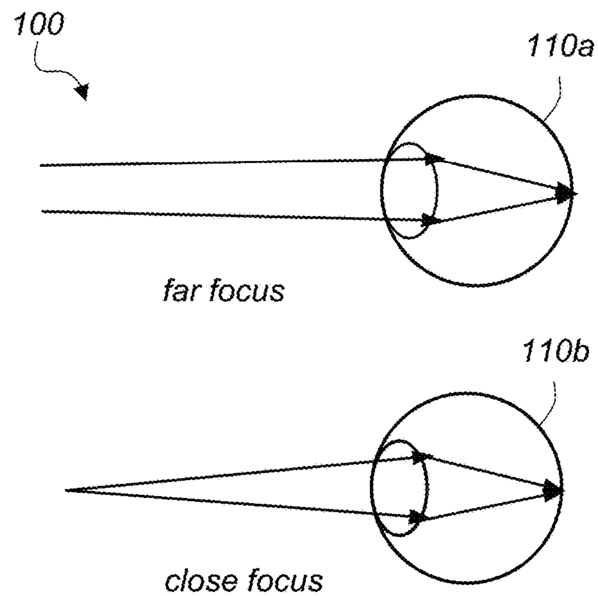


FIG. 1
(Prior Art)

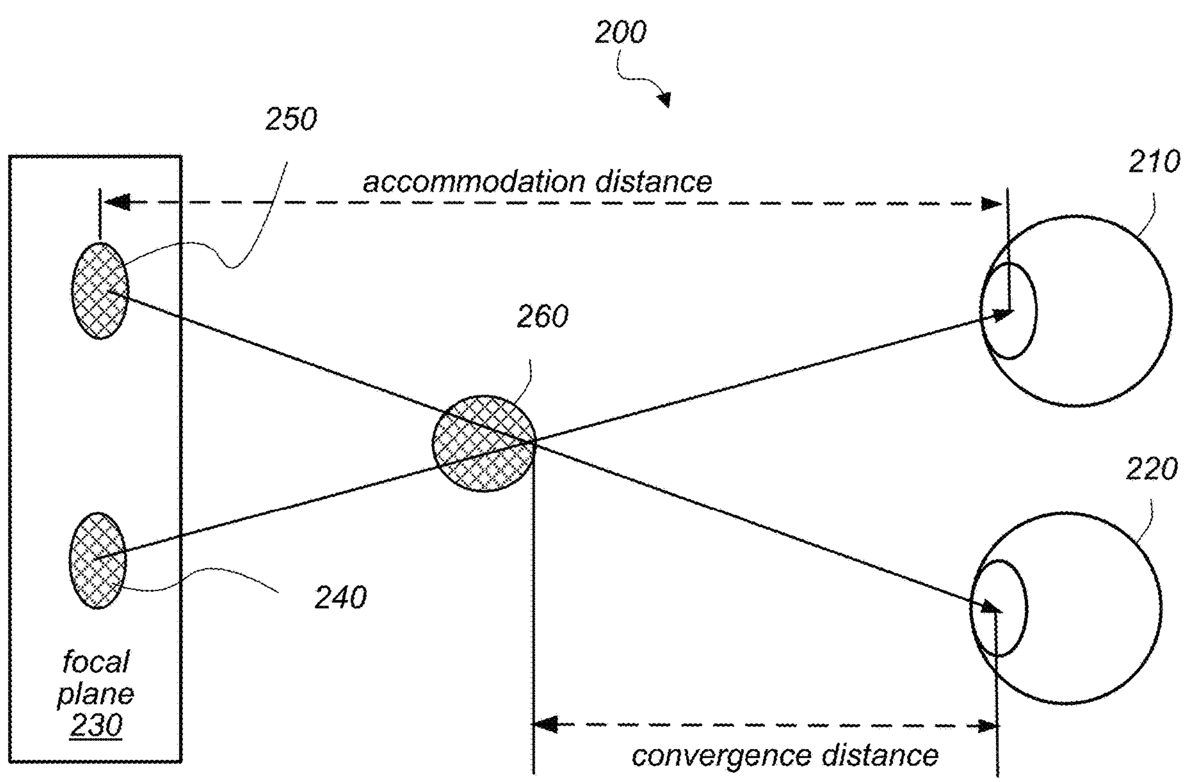


FIG. 2
(Prior Art)

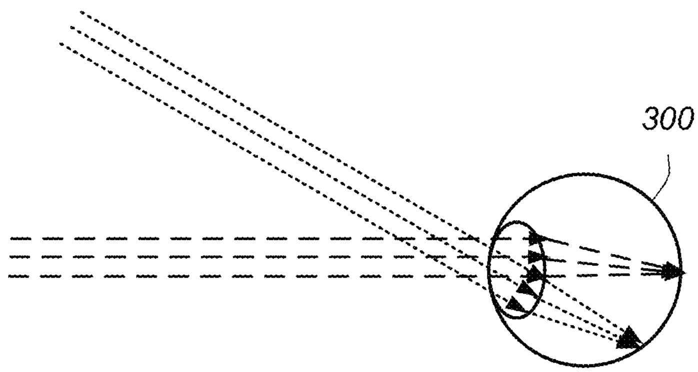


FIG. 3
(Prior Art)

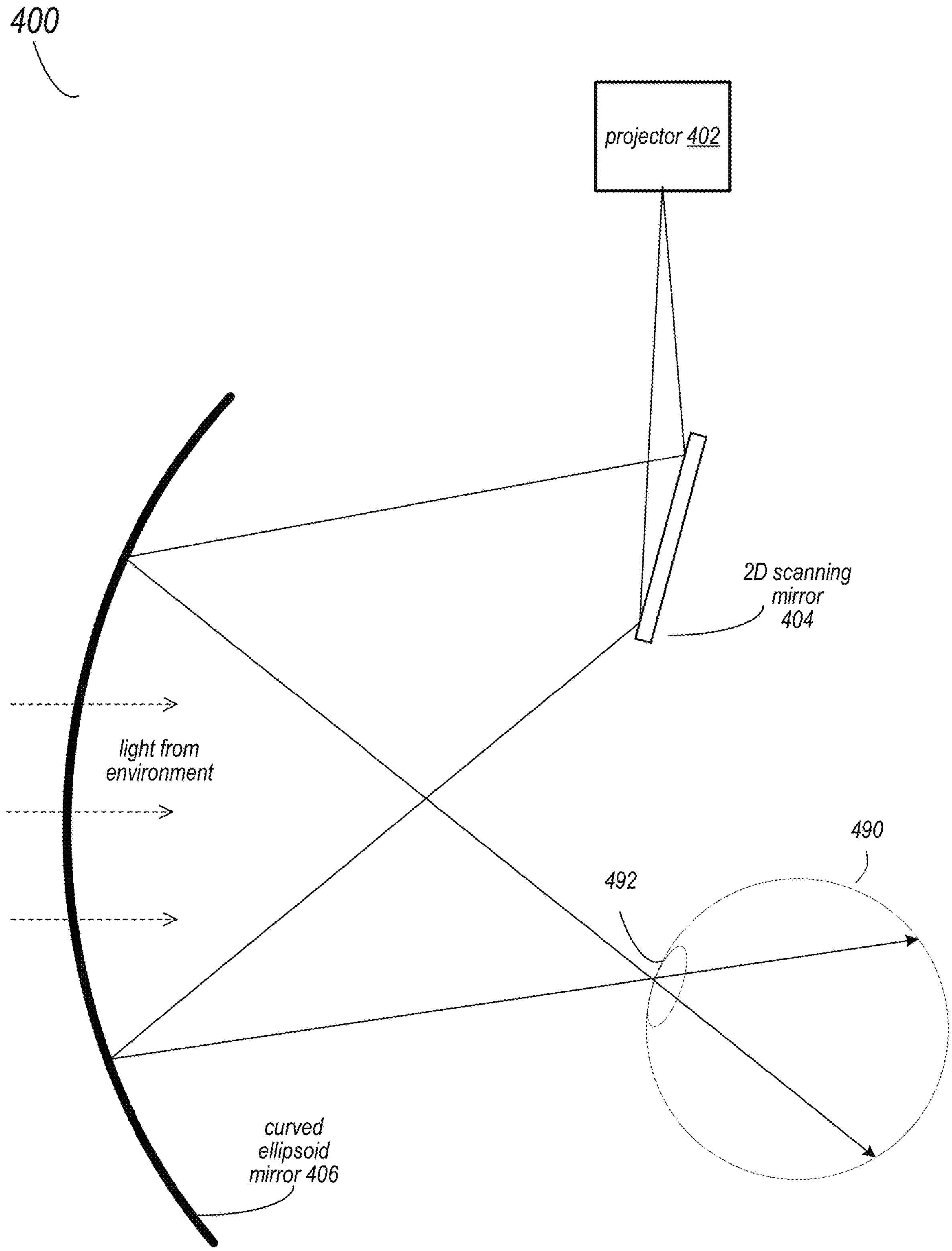
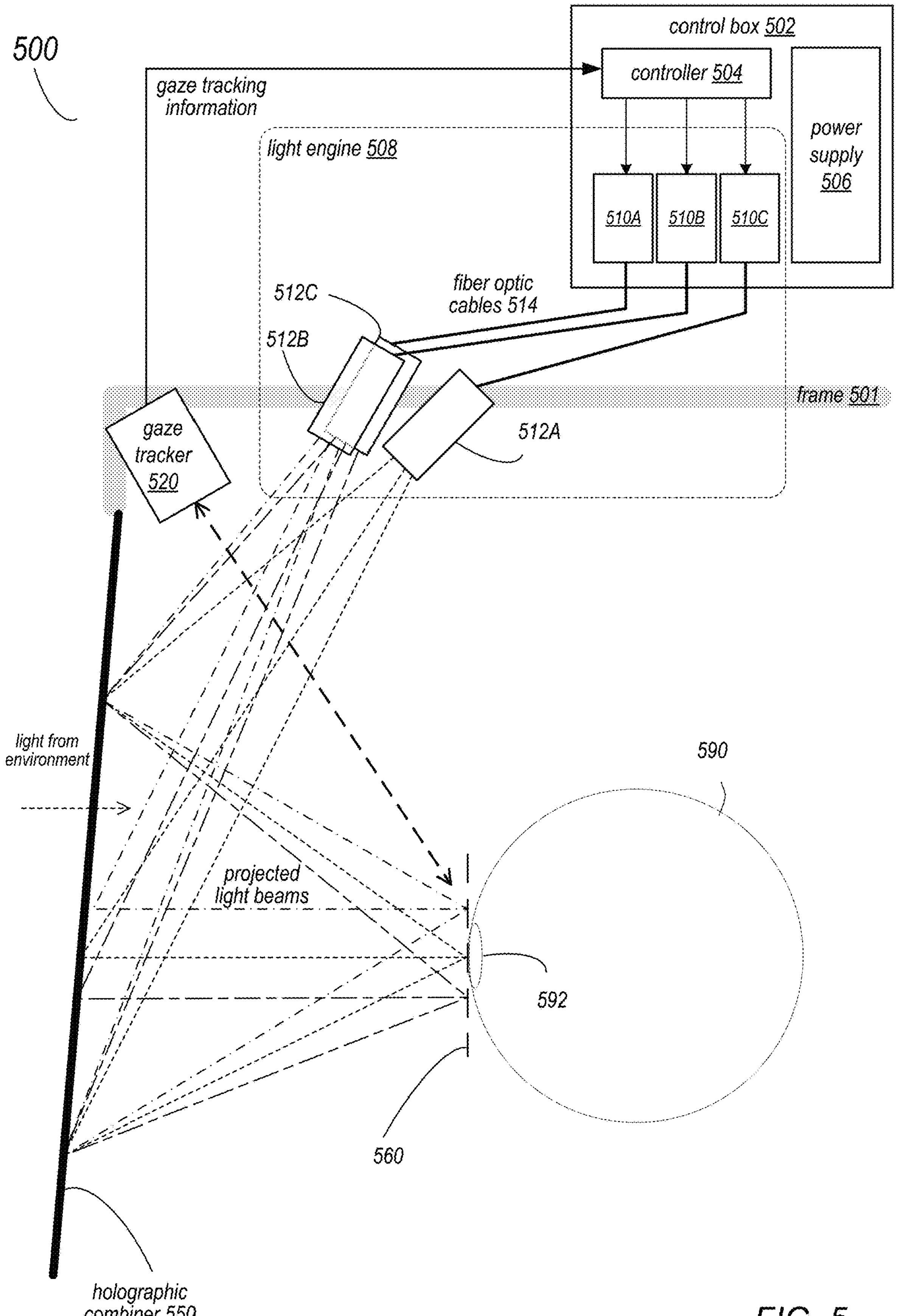

400
projector 402
2D scanning mirror 404
light from environment
490
492
curved ellipsoid mirror 406

FIG. 4



500
control box 502
controller 504
gaze tracking information
light engine 508
power supply 506
510A
510B
510C
512C
fiber optic cables 514
512B
frame 501
gaze tracker 520
512A
590
light from environment
projected light beams
592
560
holographic combiner 550

FIG. 5

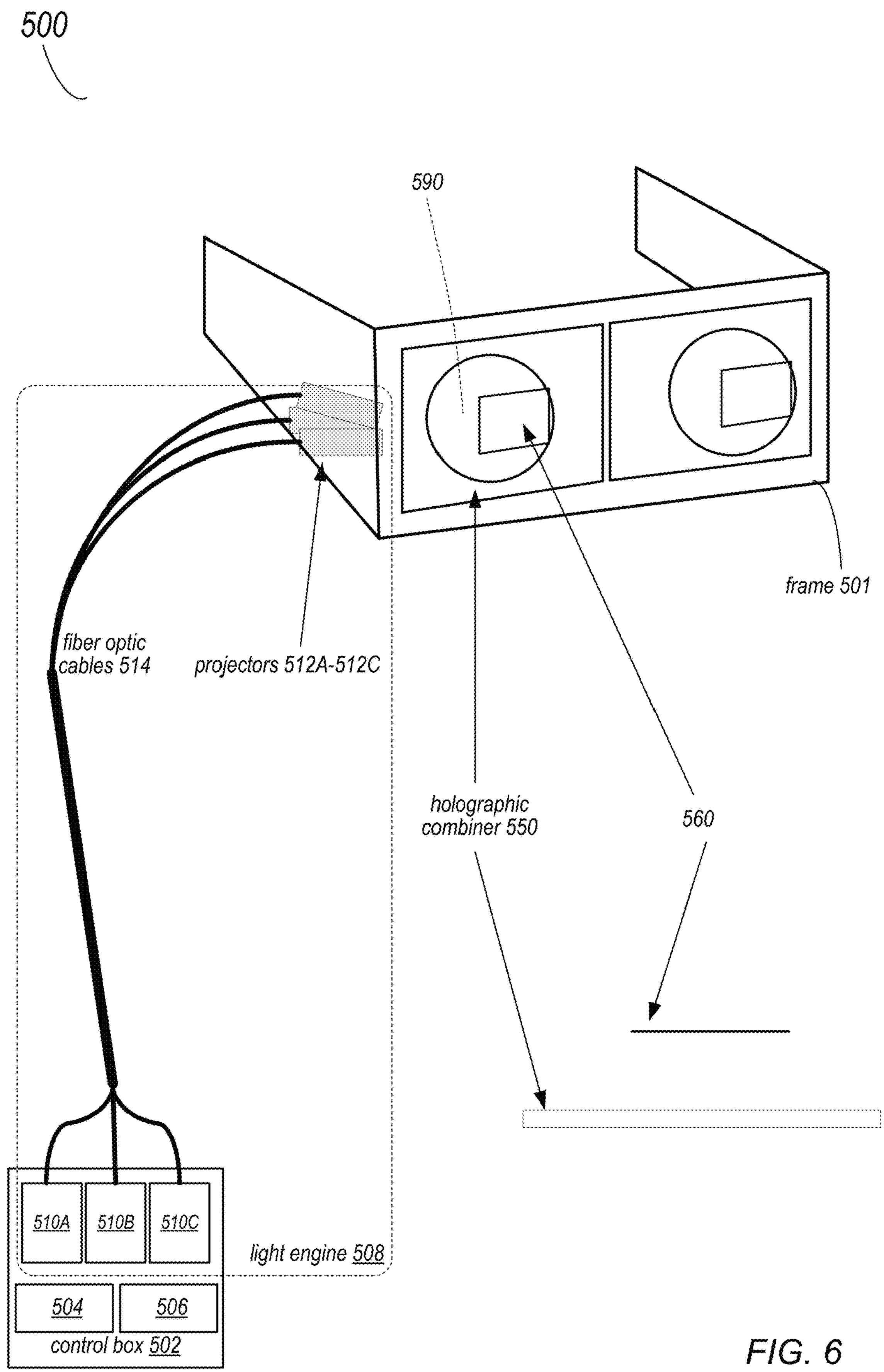

500
590
frame 501
fiber optic cables 514
projectors 512A-512C
holographic combiner 550
560
510A
510B
510C
light engine 508
504
506
control box 502

FIG. 6

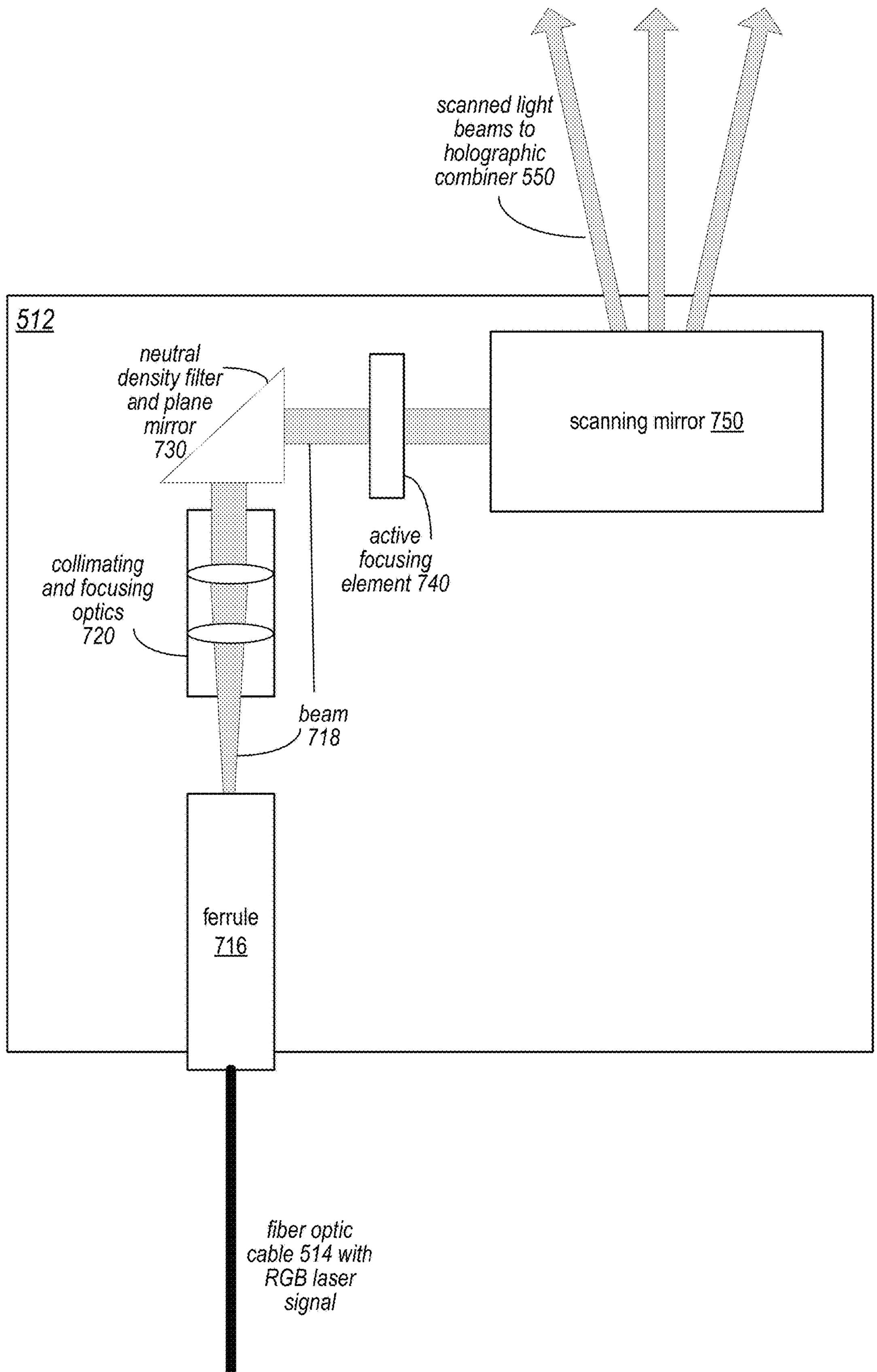
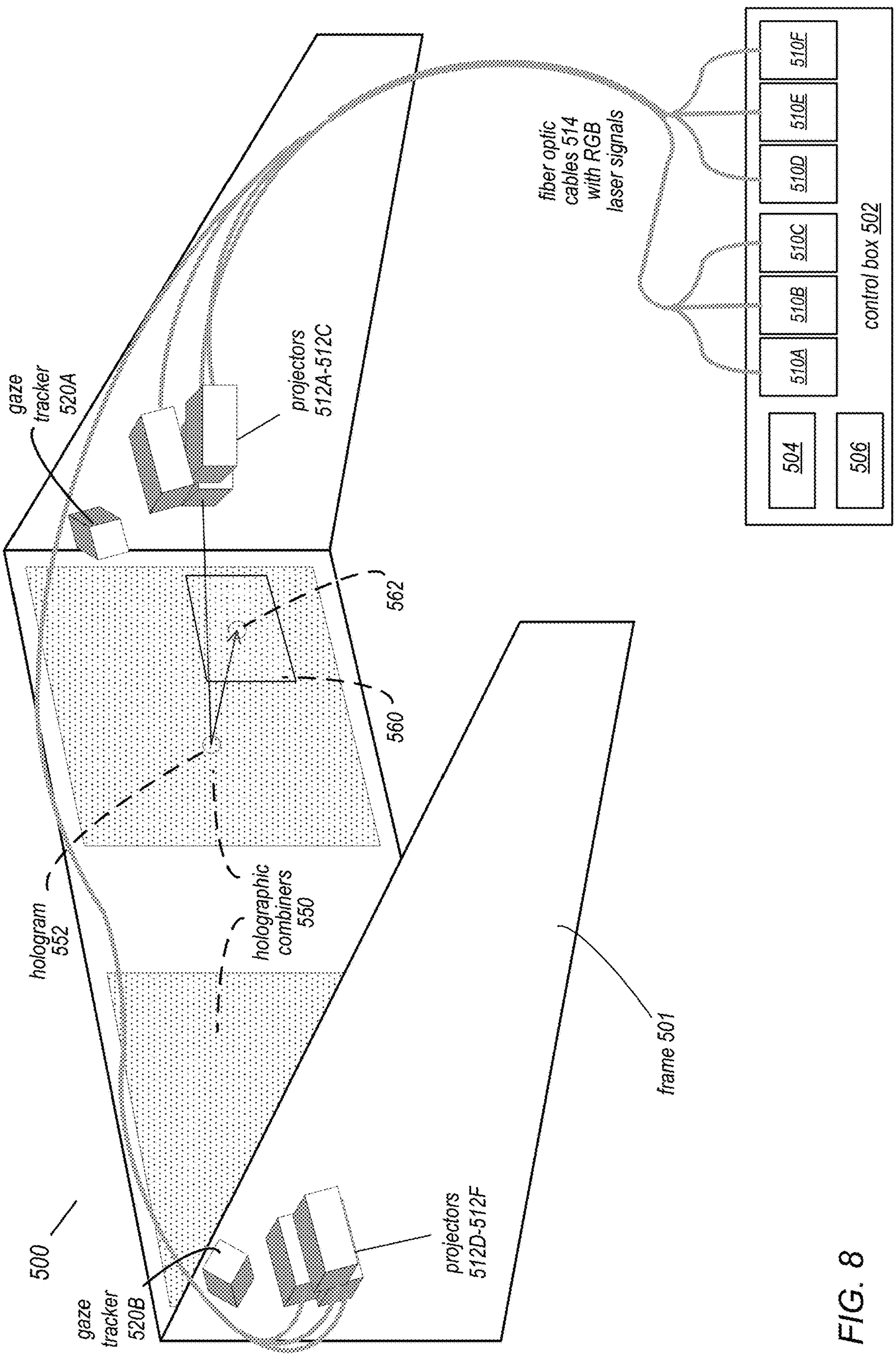

scanned light beams to holographic combiner 550
512
neutral density filter and plane mirror 730
scanning mirror 750
active focusing element 740
collimating and focusing optics 720
beam 718
ferrule 716
fiber optic cable 514 with RGB laser signal

FIG. 7



gaze tracker 520A
projectors 512A-512C
fiber optic cables 514 with RGB laser signals
510F
510E
510D
510C
510B
510A
control box 502
504
506
562
560
hologram 552
holographic combiners 550
frame 501
500
projectors 512D-512F
gaze tracker 520B

FIG. 8

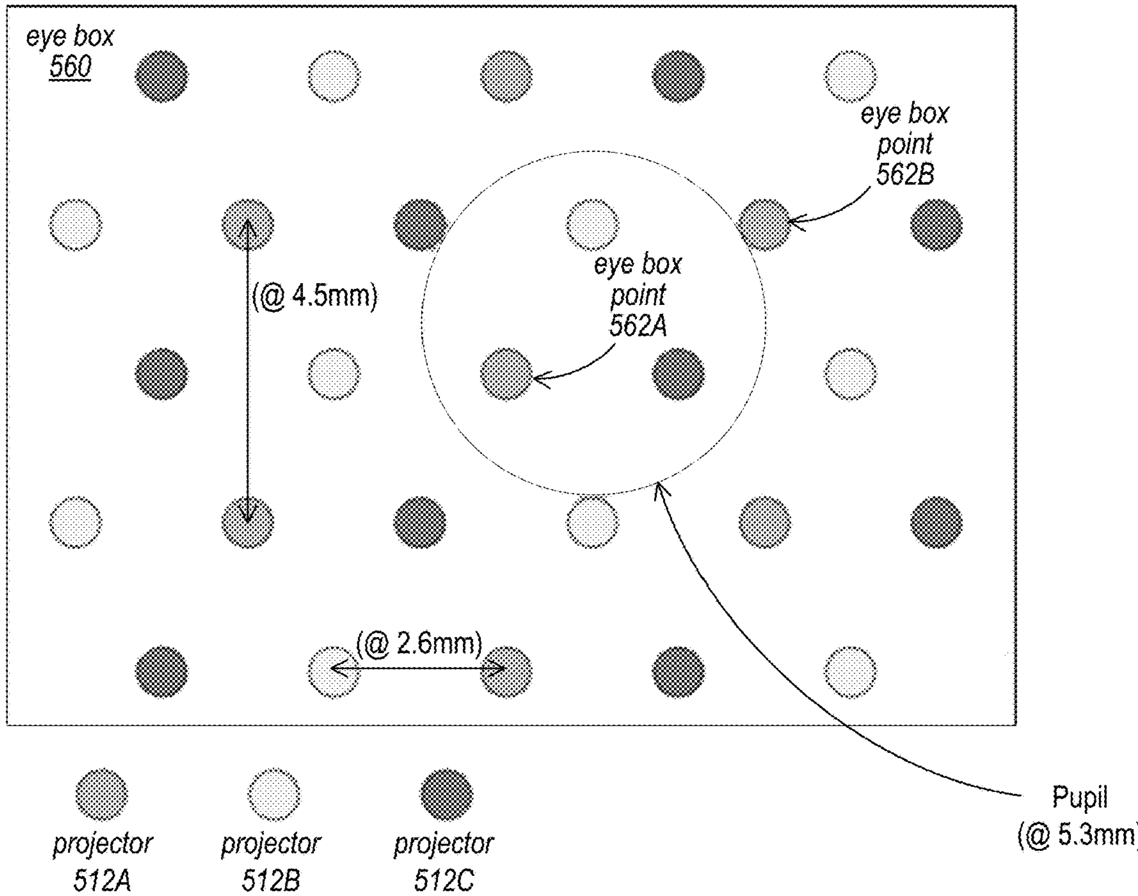
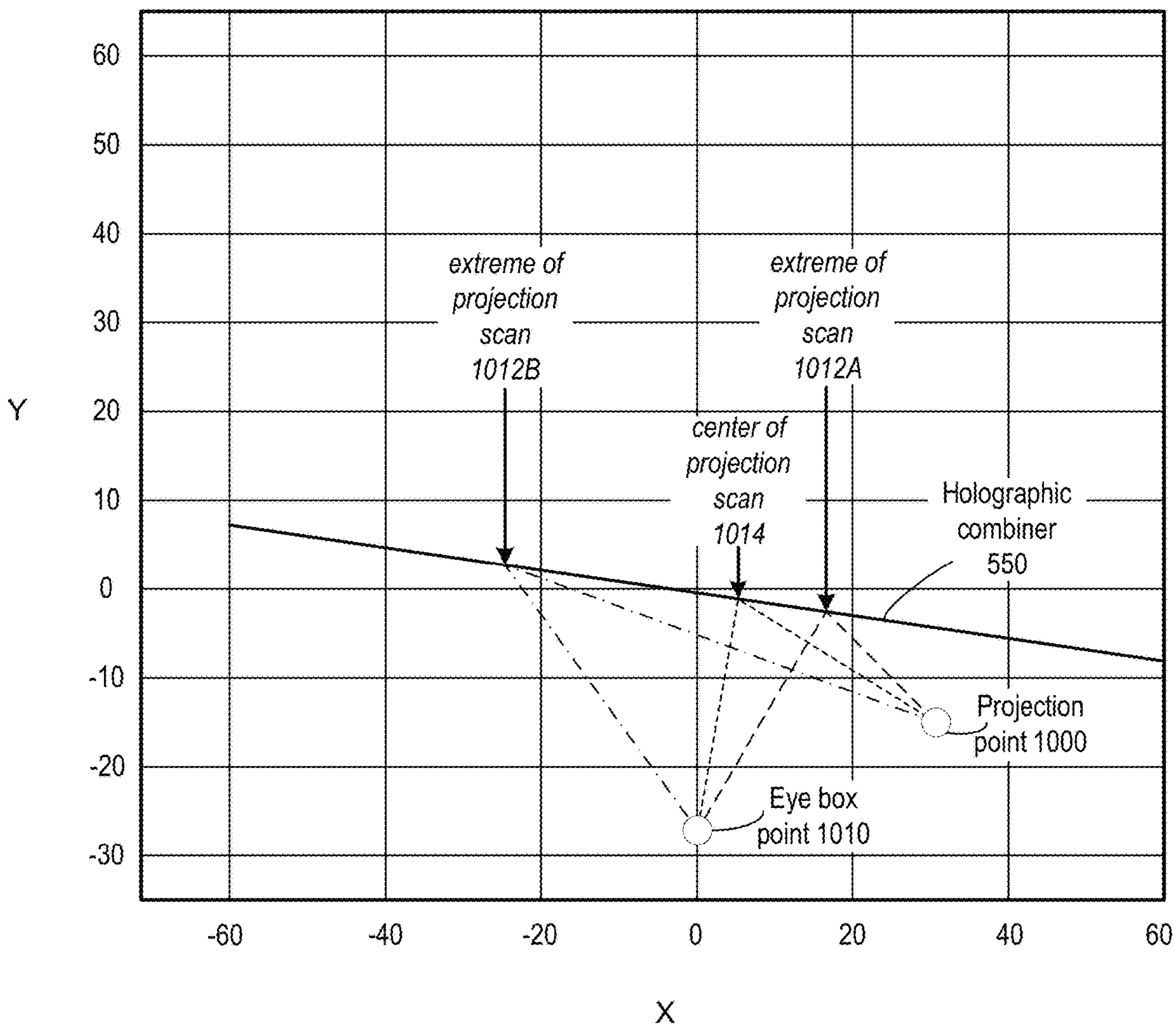

eye box
560
eye box
point
562B
eye box
point
562A
(@ 4.5mm)
(@ 2.6mm)
projector
512A
projector
512B
projector
512C
Pupil
(@ 5.3mm)

FIG. 9



60
50
40
30
20
10
0
-10
-20
-30
Y
-60
-40
-20
0
20
40
60
X
extreme of projection scan 1012B
extreme of projection scan 1012A
center of projection scan 1014
Holographic combiner 550
Projection point 1000
Eye box point 1010

FIG. 10A

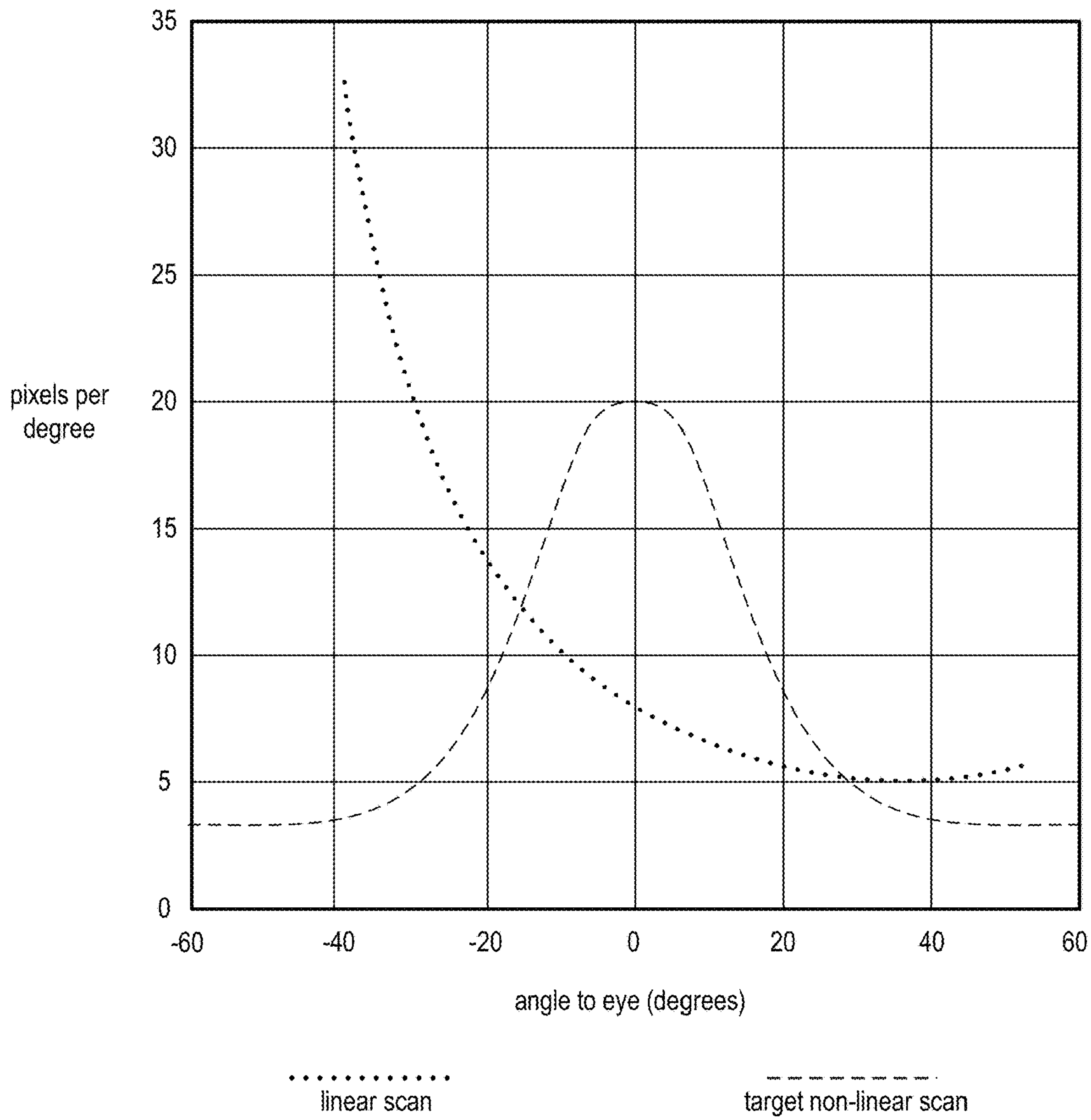

35
30
25
20
15
10
5
0
pixels per degree
-60
-40
-20
0
20
40
60
angle to eye (degrees)
linear scan
target non-linear scan

FIG. 10B

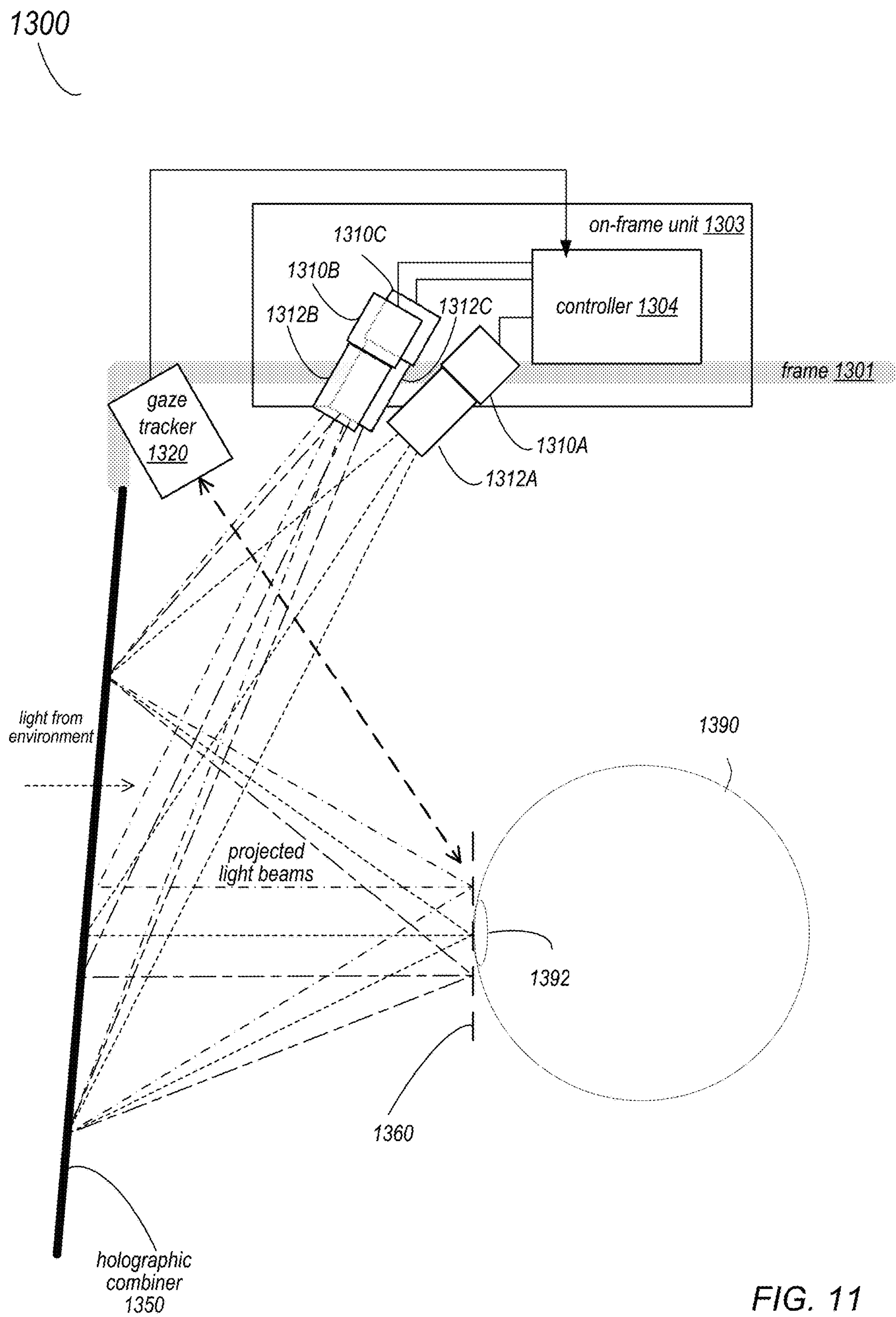
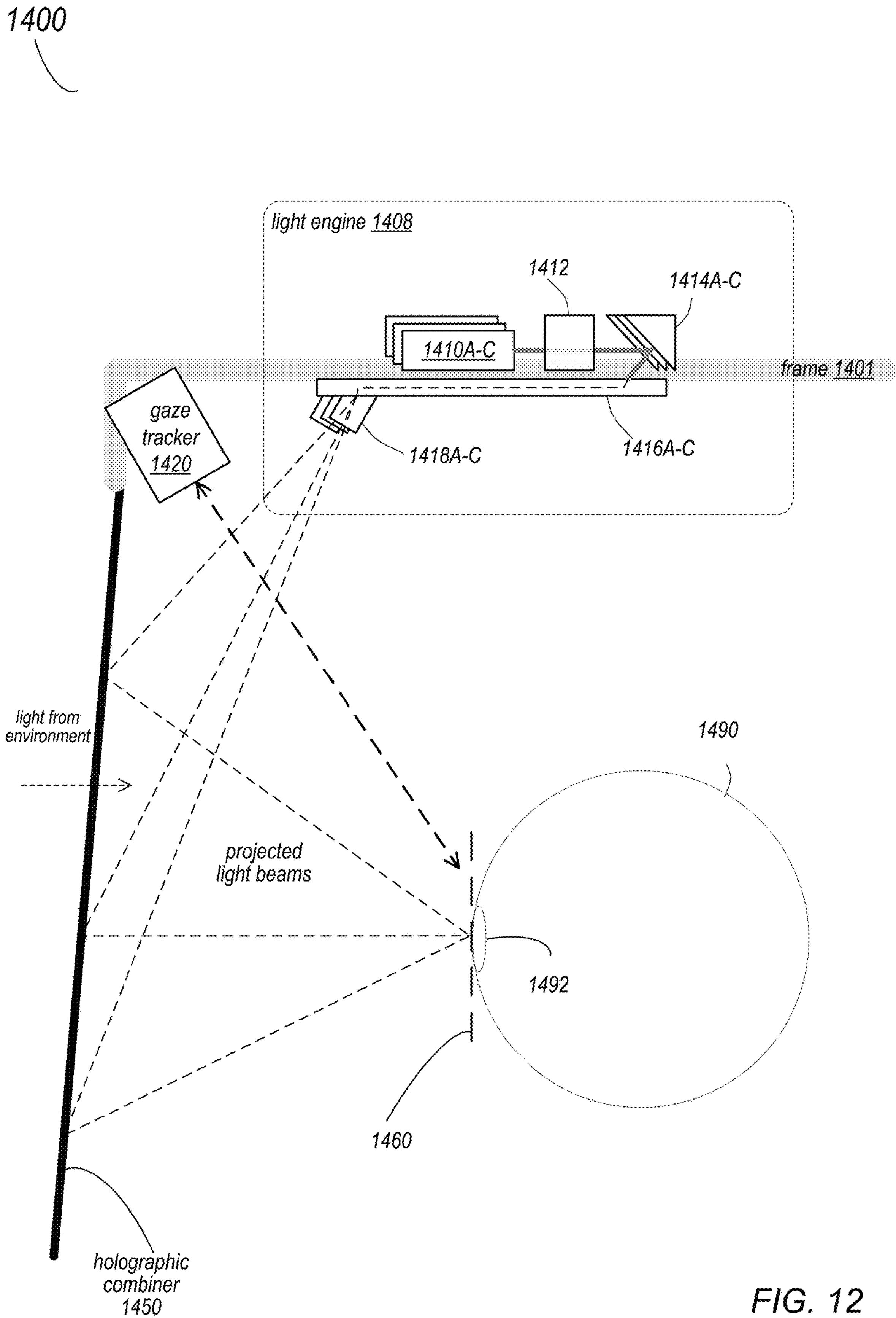
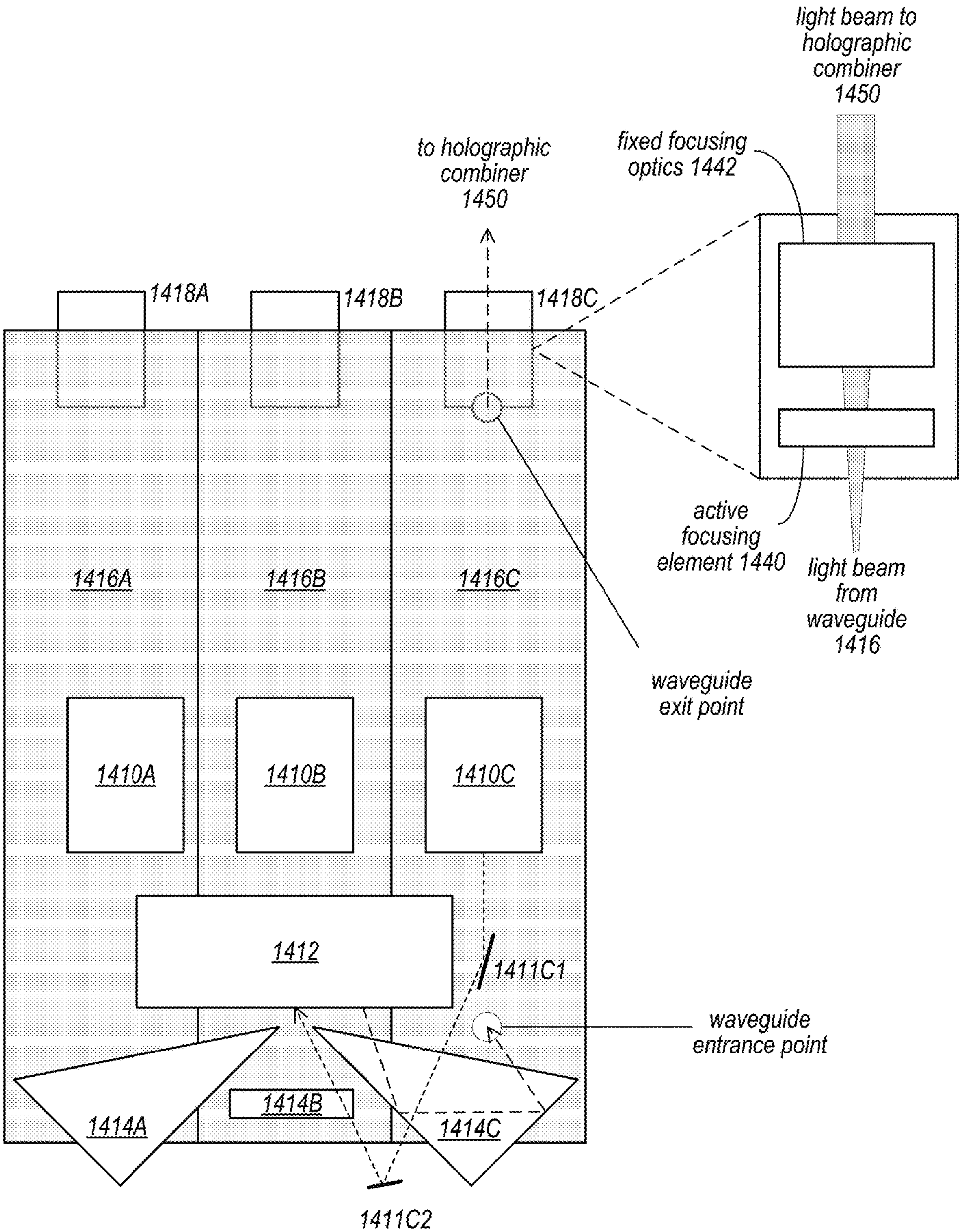

1300
on-frame unit 1303
1310C
1310B
1312B
1312C
controller 1304
frame 1301
gaze tracker 1320
1310A
1312A
light from environment
1390
projected light beams
1392
1360
holographic combiner 1350

FIG. 11



1400
light engine 1408
1412
1414A-C
1410A-C
frame 1401
gaze tracker 1420
1418A-C
1416A-C
light from environment
1490
projected light beams
1492
1460
holographic combiner 1450

FIG. 12



light beam to holographic combiner 1450
to holographic combiner 1450
fixed focusing optics 1442
1418A
1418B
1418C
active focusing element 1440
light beam from waveguide 1416
1416A
1416B
1416C
waveguide exit point
1410A
1410B
1410C
1412
1411C1
waveguide entrance point
1414A
1414B
1414C
1411C2

FIG. 13

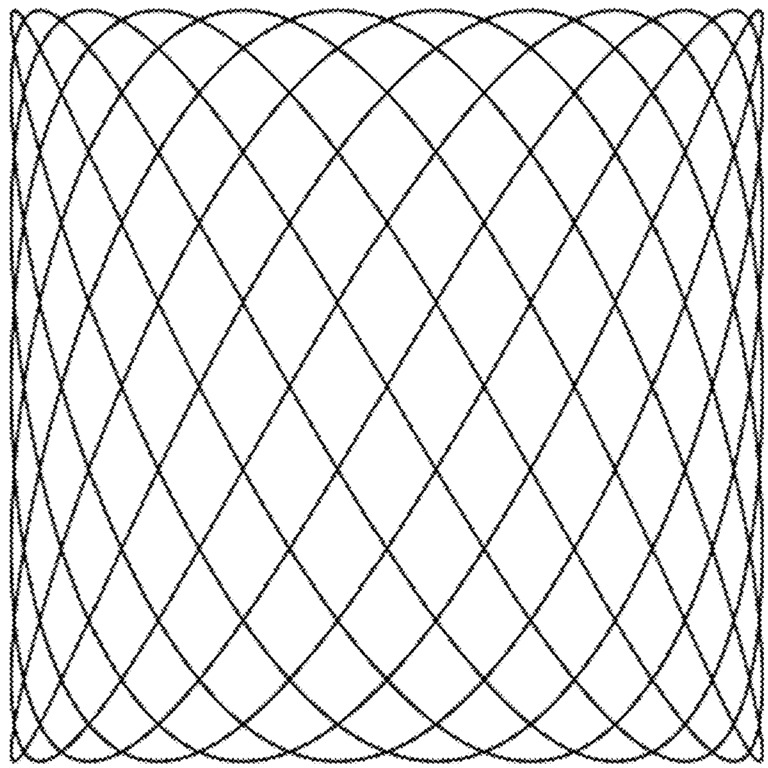


FIG. 14A

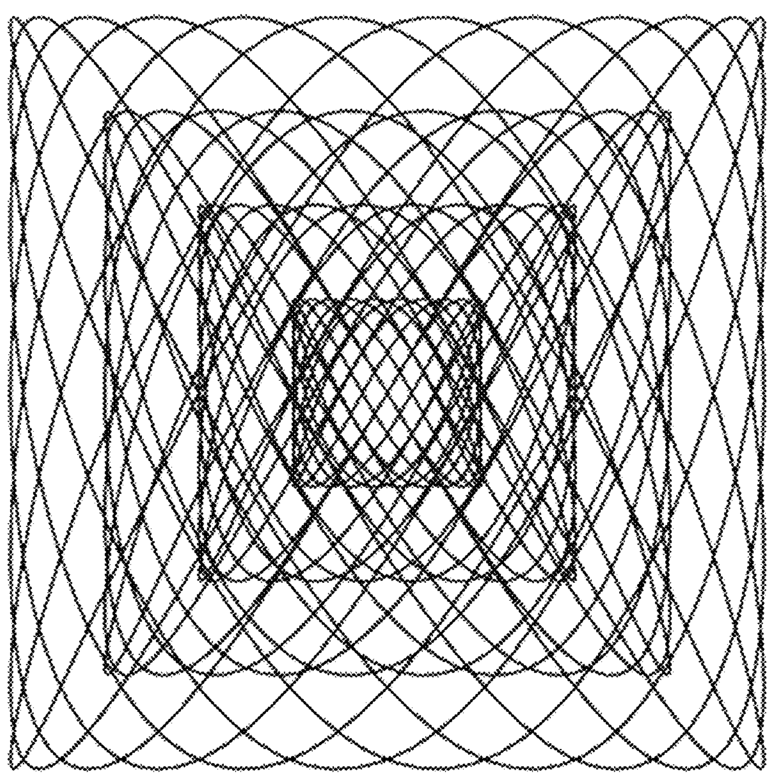


FIG. 14B

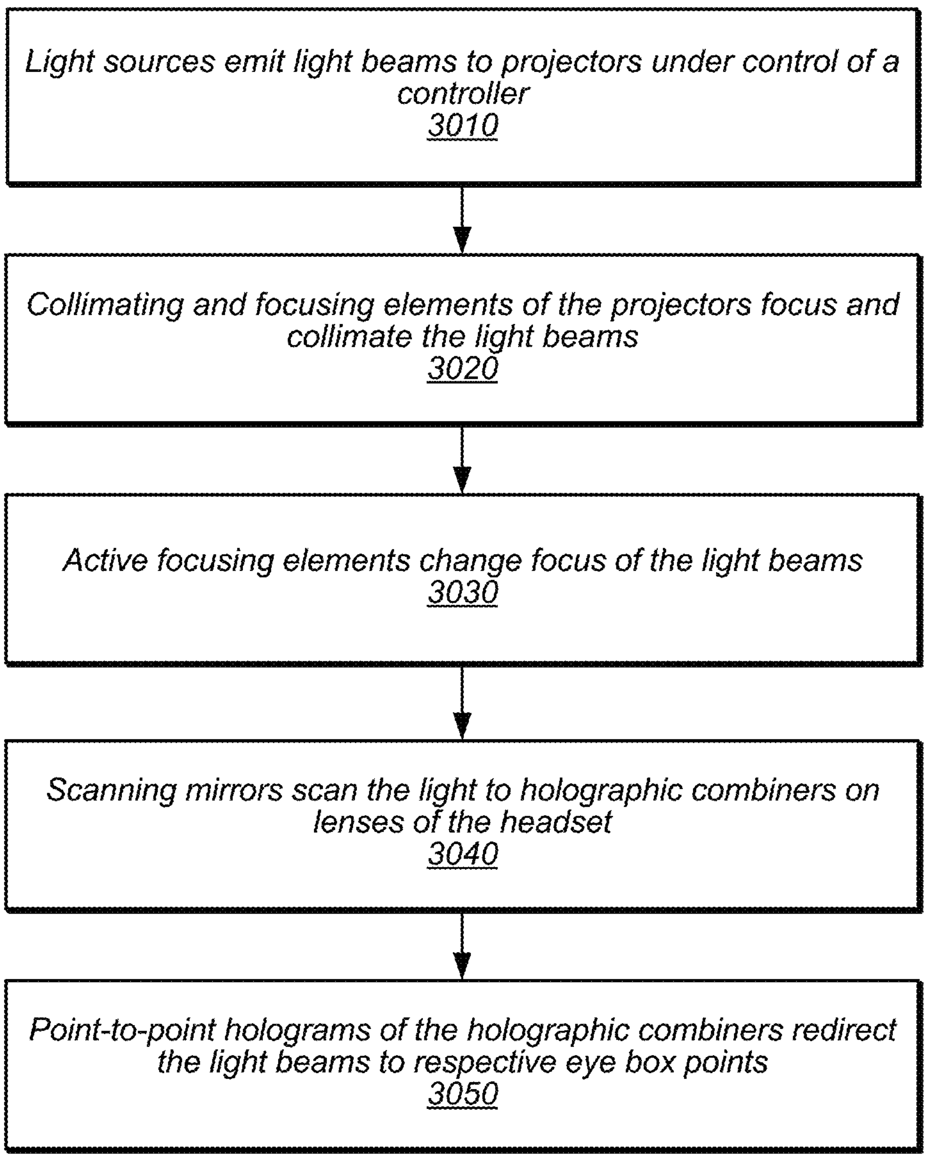

Light sources emit light beams to projectors under control of a controller
3010
Collimating and focusing elements of the projectors focus and collimate the light beams
3020
Active focusing elements change focus of the light beams
3030
Scanning mirrors scan the light to holographic combiners on lenses of the headset
3040
Point-to-point holograms of the holographic combiners redirect the light beams to respective eye box points
3050

FIG. 15

MIXED REALITY SYSTEM

This application claims benefit of priority to U.S. Provisional Application Ser. No. 62/542,257, entitled "MIXED REALITY SYSTEM," filed Aug. 7, 2017, and which is incorporated herein by reference in its entirety.

BACKGROUND

Virtual reality (VR) allows users to experience and/or interact with an immersive artificial environment, such that the user feels as if they were physically in that environment. For example, virtual reality systems may display stereoscopic scenes to users in order to create an illusion of depth, and a computer may adjust the scene content in real-time to provide the illusion of the user moving within the scene. When the user views images through a virtual reality system, the user may thus feel as if they are moving within the scenes from a first-person point of view. Mixed reality (MR) covers a spectrum from augmented reality (AR) systems that combine computer generated information (referred to as virtual content) with views of the real world to augment, or add virtual content to, a user's view of their real environment (referred to as), to augmented vitality (AV) systems that combine representations of real world objects with views of a computer generated three-dimensional (3D) virtual world. The simulated environments of virtual reality systems and/or the mixed environments of mixed reality systems may thus be utilized to provide an interactive user experience for multiple applications, such as applications that add virtual content to a real-time view of the viewer's environment, applications that generate 3D virtual worlds, interacting with virtual training environments, gaming, remotely controlling drones or other mechanical systems, viewing digital media content, interacting with the Internet, exploring virtual landscapes or environments, or the like.

However, conventional VR and MR systems may suffer from accommodation-convergence mismatch problems that cause eyestrain, headaches, and/or nausea. Accommodation-convergence mismatch arises when a VR or MR system effectively confuses the brain of a user by generating scene content that does not match the depth expected by the brain based on the stereo convergence of the two eyes of the user. For example, in a stereoscopic system the images displayed to the user may trick the eye(s) into focusing at a far distance while an image is physically being displayed at a closer distance. In other words, the eyes may be attempting to focus on a different image plane or focal depth compared to the focal depth of the projected image, thereby leading to eyestrain and/or increasing mental stress. Accommodation-convergence mismatch problems are undesirable and may distract users or otherwise detract from their enjoyment and endurance levels (i.e. tolerance) of virtual reality or mixed reality environments.

SUMMARY

Various embodiments of a mixed reality (MR) direct retinal projector system that may include an MR headset (e.g., a helmet, goggles, or glasses) that uses a reflective holographic combiner to direct light from multiple projectors of a light engine into an eye box corresponding to the user's eye, while also transmitting light from the user's environment to thus provide an augmented or mixed view of reality. The holographic combiner may be recorded with a series of point to point holograms; each projector interacts with multiple holograms to project light onto multiple locations (referred to as eye box points) in the eye box. The holograms may be arranged so that neighboring eye box points are illuminated by different projectors. The holographic combiner may be implemented by a relatively flat lens when compared to curved reflective mirrors used in other direct retinal projector systems.

The light engine may include light sources (e.g., laser diodes, LEDs, etc.) coupled to projectors that independently project light to the holographic combiner from different projection points. In some embodiments, there may be three light sources coupled to three projectors for each eye; however, more or fewer light sources and projectors may be used in some embodiments. Each light source may be an RGB light source (e.g., an RGB laser). In some embodiments, the projectors may be components of or mounted on the MR headset, and the light sources may be contained in a control box separate from the headset that may, for example, be carried on a user's hip, in a backpack, or otherwise carried or worn separately from the headset worn by the user. The control box may also contain a controller and power supply for the MR system. The light sources may be coupled to the projectors via fiber optic cables, with each light source coupled to one of the projectors. Alternatively, in some embodiments, the controller, light sources, and the projectors may be contained in a unit that is a component of or mounted on the headset.

In some embodiments, each projector may include a collimating and focusing element to focus the light beam emitted by a respective light source (e.g., RGB laser) such that, once reflected off the holographic combiner, the light is substantially collimated when it enters the subject's eye. In some embodiments, each projector may include a two-axis scanning mirror to scan the focused light from a respective light source to the holographic combiner; the light source may be appropriately modulated under control of the controller to generate a desired image. In some embodiments, each projector may include an active focusing element that may, for example, be used to change focus of the light beam as the light beam is scanned across a slow (horizontal) axis by the scanning mirror. This may also enable beams that diverge into the eye to, rather than being collimated, match the beam divergence of the supposed depth of the virtual object(s) being projected by the light engine.

In some embodiments, the MR headset may include a gaze tracking component implemented according to any of a variety of gaze tracking technologies that may, for example, provide gaze tracking input to the controller so that the light beams projected by the light engine can be adjusted according to the current position of the subject's eyes. For example, different ones of the light sources and projectors may be activated to project light onto different eye box points based on the current position of the subject's eyes.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an example of different types of eye focus.

FIG. **2** illustrates one embodiment of a conventional near-eye virtual reality system.

FIG. **3** illustrates an example of parallel light beams entering an eye.

FIG. **4** illustrates a direct retinal projector system that uses a curved ellipsoid mirror to direct light from a projector into a subject's eye, while also transmitting light from the environment to the subject's eye.

FIG. **5** illustrates a mixed reality (MR) system that uses a reflective holographic combiner to direct light from multiple projectors into a subject's eye, while also transmitting light from the environment to the subject's eye, according to some embodiments.

FIG. **6** illustrates an MR headset that includes a reflective holographic combiner to direct light from a light engine into a subject's eye, while also transmitting light from the environment to the subject's eye, according to some embodiments.

FIG. **7** illustrates components of a projector, according to some embodiments.

FIG. **8** illustrates an MR system that includes a headset with projectors and a separate control box containing light sources, according to some embodiments.

FIG. **9** illustrates an example eye box of an MR system, according to some embodiments.

FIGS. **10**A and **10**B illustrate linear and non-linear slow axis scans in an MR system, according to some embodiments.

FIG. **11** illustrates an embodiment of an MR system in which the projectors and light sources are contained in an on-frame unit.

FIG. **12** illustrates a light engine in an MR system that uses a single scanning mirror and waveguides to direct light from multiple independent light sources to focusing elements that provide different projection points to a reflective holographic combiner, according to some embodiments.

FIG. **13** further illustrates components of a light engine as illustrated in FIG. **12**, according to some embodiments.

FIGS. **14**A and **14**B illustrate using resonance techniques on both axes of a scanning mirror, according to some embodiments.

FIG. **15** is a high-level flowchart of a method of operation for an MR system as illustrated in FIGS. **5** through **11**, according to some embodiments.

This specification includes references to "one embodiment" or "an embodiment." The appearances of the phrases "in one embodiment" or "in an embodiment" do not necessarily refer to the same embodiment. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure.

"Comprising." This term is open-ended. As used in the claims, this term does not foreclose additional structure or steps. Consider a claim that recites: "An apparatus comprising one or more processor units . . . ." Such a claim does not foreclose the apparatus from including additional components (e.g., a network interface unit, graphics circuitry, etc.).

"Configured To." Various units, circuits, or other components may be described or claimed as "configured to" perform a task or tasks. In such contexts, "configured to" is used to connote structure by indicating that the units/circuits/components include structure (e.g., circuitry) that performs those task or tasks during operation. As such, the unit/circuit/component can be said to be configured to perform the task even when the specified unit/circuit/component is not currently operational (e.g., is not on). The units/circuits/components used with the "configured to" language include hardware—for example, circuits, memory storing program instructions executable to implement the operation, etc. Reciting that a unit/circuit/component is "configured to" perform one or more tasks is expressly intended not to invoke 35 U.S.C. § 112, paragraph (f), for that unit/circuit/component. Additionally, "configured to" can include generic structure (e.g., generic circuitry) that is manipulated by software or firmware (e.g., an FPGA or a general-purpose processor executing software) to operate in manner that is capable of performing the task(s) at issue. "Configure to" may also include adapting a manufacturing process (e.g., a semiconductor fabrication facility) to fabricate devices (e.g., integrated circuits) that are adapted to implement or perform one or more tasks.

"First," "Second," etc. As used herein, these terms are used as labels for nouns that they precede, and do not imply any type of ordering (e.g., spatial, temporal, logical, etc.). For example, a buffer circuit may be described herein as performing write operations for "first" and "second" values. The terms "first" and "second" do not necessarily imply that the first value must be written before the second value.

"Based On" or "Dependent On." As used herein, these terms are used to describe one or more factors that affect a determination. These terms do not foreclose additional factors that may affect a determination. That is, a determination may be solely based on those factors or based, at least in part, on those factors. Consider the phrase "determine A based on B." While in this case, B is a factor that affects the determination of A, such a phrase does not foreclose the determination of A from also being based on C. In other instances, A may be determined based solely on B.

"Or." When used in the claims, the term "or" is used as an inclusive or and not as an exclusive or. For example, the phrase "at least one of x, y, or z" means any one of x, y, and z, as well as any combination thereof.

DETAILED DESCRIPTION

Various embodiments of a mixed reality (MR) direct retinal projector system are described that may, for example, resolve the convergence-accommodation conflict in head-mounted AR, MR, and VR systems. Embodiments of an MR headset (e.g., a helmet, goggles, or glasses) are described that may include or implement different techniques and components of the MR system. In some embodiments, an MR headset may include a reflective holographic combiner to direct light from multiple (e.g., three) projectors of a light engine into an eye box corresponding to the user's eye, while also transmitting light from the user's environment to thus provide an augmented or mixed view of reality. The holographic combiner may be recorded with a series of point to point holograms; each projector interacts with multiple holograms to project light onto multiple locations (referred to as eye box points) in the eye box. The holograms may be arranged so that neighboring eye box points are illuminated by different projectors. In some embodiments, only one projector is active at a given time; when activated, a projector projects light from a corresponding light source (e.g., an RGB laser) to all of its eye box points. However, in some embodiments, more than one projector, or all of the projectors, may be active at the same time.

The light engine may include light sources (e.g., laser diodes, LEDs, etc.) coupled to projectors that independently project light to the holographic combiner from different projection points. In some embodiments, there may be three light sources coupled to three projectors for each eye; however, more or fewer light sources and projectors may be used in some embodiments. Each light source may be an RGB light source (e.g., an RGB laser). In some embodiments, the projectors may be components of or mounted on the MR headset, and the light sources may be contained in a control box separate from the headset that may, for example, be carried on a user's hip, in a backpack, or otherwise carried or worn separately from the headset worn by the user. The control box may also contain a controller and power supply for the MR system. The light sources may be coupled to the projectors via fiber optic cables, with each light source coupled to one of the projectors. Alternatively, in some embodiments, the controller, light sources, and the projectors may be contained in a unit that is a component of or mounted on the headset.

In some embodiments, each projector may include a collimating and focusing element to focus the light beam emitted by a respective light source (e.g., an RGB laser light source) such that, once reflected by the holographic combiner, the light is substantially collimated when it enters the subject's eye. In some embodiments, each projector may include a two-axis scanning mirror to scan the focused light from a respective light source to the holographic combiner; the light source may be appropriately modulated under control of the controller to generate a desired image. In some embodiments, each projector may include an active focusing element that may, for example, be used to change focus of the light beam as the light beam is scanned across a slow (horizontal) axis by the scanning mirror. This may also enable beams that diverge into the eye to, rather than being collimated, match the beam divergence of the supposed depth of the virtual object(s) being projected by the light engine.

In some embodiments, the MR headset may include a gaze tracking component implemented according to any of a variety of gaze tracking technologies that may, for example, provide gaze tracking input to the controller so that the light beams projected by the light engine can be adjusted according to the current position of the subject's eyes. For example, different ones of the light sources and projectors may be activated to project light onto different eye box points based on the current position of the subject's eyes.

Accommodation and Convergence in MR/VR Systems

The human brain typically uses two cues to gauge distance: accommodation (i.e., eye focus) and eye convergence (i.e., the stereoscopic perspective difference between the two eyes). Conventional near-eye systems typically use separate miniature screens for each respective eye to project the images intended for the left eye and the right eye, as well as optics to allow a user to comfortably focus the eyes at a far distance during viewing of the left eye and right eye images. Conventional near-eye systems thus produce conflicting visual cues since the resulting three-dimensional (3D) image produced by the brain effectively appears at a convergence distance that is closer than the accommodation distance that each eye focuses on separately, thereby leading to the possibility of headache and/or nausea over time. Heavy users of conventional systems may potentially train themselves to compensate for accommodation-convergence mismatch, but a majority of users might not.

Mixed reality (MR) systems typically add information and graphics to an existing scene being viewed by a user. In some embodiments, MR may be a powerful experience, since the user can see both the projected images and/or sprites (i.e., the augmented world) as well as the surrounding scene (i.e., the real world) directly through the MR system rather than using camera systems to project a version of the surrounding scene less accurately onto screen displays for each eye.

FIG. **1** depicts an example of different types of eye focus. In system **100** of FIG. **1**, an eye **110**A may be selectively configured to focus at a far distance, as shown by the incident light originating from a distant location and focusing onto the retina (i.e., the back internal surface) of eye **110**A by the internal lens of eye **110**A. In another embodiment, eye **110**A may instead be selectively configured for a close focus scenario, as shown by light from a nearby location being incident upon the eye and focusing onto the retina.

FIG. **2** illustrates one embodiment of a conventional near-eye system **200**. As depicted, right eye **210** and left eye **220** are focused on a focal plane **230** where an image for right eye **240** and an image for left eye **250**, respectively, are displayed. As right eye **210** and left eye **220** focus on their respective images on focal plane **230**, the brain of the user combines the images into a resulting 3D image **260**. In one embodiment, the accommodation distance may be the distance between focal plane **230** and an eye of the user (e.g., right eye **210** and/or left eye **220**), and the convergence distance may be the distance between resulting 3D image **260** and an eye of the user. Since, as depicted in FIG. **2**, the accommodation distance differs from the convergence distance, conventional near-eye system **200** therefore results in an accommodation-convergence mismatch and may cause discomfort for the user as described above.

FIG. **3** illustrates an example of parallel light beams entering an eye **300**. As shown, various sets of parallel light beams that enter eye **300** are focused by eye **300** such that the parallel beams within a respective set land at the same place on the retina of eye **300**.

Direct Retinal Projector System with Scanning Mirror and Ellipsoid Mirror

A direct retinal projector system may be implemented as a headset (e.g., a helmet, goggles, or glasses) that includes a scanning projector, curved ellipsoid mirror, gaze tracking technology, and a secondary scanning mirror. FIG. **4** illustrates a direct retinal projector system **400** that scans virtual reality (VR) images, pixel, by pixel, to a subject's eye **490**. In some embodiments, of a direct retinal projector system **400**, under control of a controller (not shown), light beams are scanned by a scanning projector **402** to a secondary scanning mirror **404**, and the light beams are then scanned by the scanning mirror **404** to different positions on a curved ellipsoid mirror **406** in front of the subject's eye **490** according to the current position of the subject's eye **490** as determined by gaze tracking technology (not shown), and reflected off the curved mirror **406** through the subject's pupil **492** to form the images on the subject's retina to thus provide a VR view to the subject. Unlike conventional screen-based VR/MR systems, there is no intermediate image on a screen or surface that the subject views. The direct retinal projector system **400** may at least partially eliminate eye lens accommodation from the retinal projection focus to help eliminate the accommodation convergence mismatch. In some embodiments, to provide an MR experience to the user, the curved mirror **406** may allow light from the subject's environment to pass through the mirror to the subject's eye **490** while simultaneously reflecting the light beams generated by the projector **402** to the subject's eye **490**, thus enabling the subject to see elements of both an external (real) scene and the virtual reality (VR) images projected by the projector. Note that the direct retinal projector system **400** is shown for only one eye; generally but not necessarily, there will be a second direct retinal projector system **400** for the second eye.

In the direct retinal projector system **400** as illustrated in FIG. **4**, the curved ellipsoid mirror **406** bulges outward significantly, and therefore the headset may be cumbersome and odd looking when worn by a user. In addition, the projector **402** may emit relatively small beams (e.g., 1 mm diameter) that may limit resolution, and the system **400** may have a relatively limited field of view. In addition, the system is mechanically complex; for example, the secondary scanning mirror **404** for adjusting for different eye positions adds complexity. Further, the projector **402** and scanning mirror **404** may be relatively large, further adding to the bulk of the headset.

Direct Retinal Projector MR System with Holographic Combiner

Embodiments of a direct retinal projector MR system are described that include an MR headset (e.g., helmet, goggles, or glasses) with reflective holographic combiners to direct light from light engines into the user's eyes, while also transmitting light from the user's environment to thus provide an augmented or mixed view of reality. The light engines may include multiple light sources (e.g., laser diodes, LEDs, etc.) coupled to projectors that independently project light to the holographic combiners from different projection points. The holographic combiners may, for example, be implemented as holographic films on relatively flat lenses when compared to the curved ellipsoid mirrors **406** of the system **400** as illustrated in FIG. **4**, and thus do not bulge as do the mirrors **406** in that system, making the headset less bulky, more comfortable to wear, and more normal looking; the headset may, for example, be implemented as a relatively normal-looking pair of glasses. In some embodiments, the projectors may be components of or mounted on the MR headset, and the light sources may be contained in a control box separate from the headset that may, for example, be carried on a user's hip, in a backpack, or otherwise carried or worn separately from the headset worn by the user. The control box may also contain a controller and power supply for the MR system. The light sources may be coupled to the projectors via fiber optic cables, with each light source coupled to one of the projectors. Alternatively, in some embodiments, the controller, light sources, and the projectors may be contained in a unit that is a component of or mounted on the headset.

Embodiments of the MR system may not require extra moving parts or mechanically active elements such as scanning mirror **404** to compensate for the eye changing position in the eye box or for changing optical power from the holographic combiner during the scan, which simplifies the system architecture when compared to the direct retinal projector system of FIG. **4**. Thus, the light engine may be implemented as a relatively small solid-state system, reducing the mechanical complexity and bulk of the MR headset when compared to a system as illustrated in FIG. **4**.

FIGS. **5** through **16** illustrate architecture, components, and operation of example embodiments of a direct retinal projector MR system. FIG. **15** is a high-level flowchart of a method of operation for an MR system as illustrated in FIGS. **5** through **11**, according to some embodiments. Elements of FIG. **15** are explained in greater detail in FIGS. **5** through **11**. As indicated at **3010**, light sources (e.g., RGB lasers) emit light beams to projectors under control of a controller. In some embodiments, the light sources may be located in a control box and coupled to the projectors by fiber optic cables, for example as illustrated in FIG. **5**. Alternatively, in some embodiments, the light sources may be coupled directly to the projectors in an on-frame unit, for example as illustrated in FIG. **11**. As indicated at **3020**, collimating and focusing optic elements of the projectors refract the light to focus and collimate the light beams, for example as illustrated in FIG. **7**. As indicated at **3030**, active focusing elements of the projectors may change the focus of the light beams, for example as illustrated in FIG. **7**. As indicated at **3040**, scanning mirrors (e.g., 2D scanning microelectromechanical systems (MEMS) mirrors) of the projectors scan the light beams to holographic combiners on lenses of the headset, for example as illustrated in FIG. **7**. As indicated at **3050**, point-to-point holograms of the holographic combiner redirect the light beams to respective eye box points, for example as illustrated in FIGS. **8** and **9**. In some embodiments, the subject's pupil position may be tracked by a gaze tracking component, and the MR system may selectively illuminate different eye box points according to the tracking information by selectively activating different ones of the light sources and projectors, for example as illustrated in FIGS. **5** and **11**.

FIGS. **5** and **6** illustrate a mixed reality (MR) system **500** that uses a reflective holographic combiner **550** to direct light projected by multiple projectors **512** into a subject's eye **590**, while also transmitting light from the environment to the subject's eye **590**, according to some embodiments. In some embodiments, the MR system **500** may include a headset (e.g., a helmet, goggles, or glasses as shown in FIG. **6**) that includes a frame **501**, multiple projectors **512** (three, in this example), a gaze tracking component (gaze tracker **520**), and a lens that includes a holographic combiner **550**, for example implemented as one or more layers of holographic film on either side of, or embedded in, the lens. The lens may be a piece of curved glass or plastic with optical power depending on the user's particular requirements, or alternatively a piece of flat or curved glass or plastic with no optical power. Note that, for simplicity, the system **500** is shown for only one eye; generally but not necessarily, there will be projectors **512**, a gaze tracker **520**, and a lens with holographic combiner **550** for the second eye.

In some embodiments, the MR system **500** may also include a separate control box **502** that includes multiple light sources **510** (three, in this example), and a controller **504** and power supply **506** for the MR system **500**. The light sources **510** may, for example, be RGB lasers. The control box **502** may, for example, be worn on the user's hip, or otherwise carried or worn by the user. The light sources **510** may be coupled to the projectors **512** by fiber optic cables **514**, with each light source **510** coupled to one projector **512**. In some embodiments, the control box may include separate sets of light sources **510** for each eye **590**, with the light sources **510** for each eye connected to the projectors **512** on respective sides of the frame **501** by fiber optic cables **514**. The light sources **510**, fiber optic cables **514**, and projectors **512** for an eye **590** may be referred to as a light engine **508**. Thus, the system **500** may include two light engines **508**, with one for each eye.

The controller **504** may control operation of the light engine(s) **508**. The controller **504** may be integrated in the control box **502**, or alternatively may be implemented at least in part by a device (e.g., a personal computer, laptop or notebook computer, smartphone, pad or tablet device, game controller, etc.) coupled to the control box **502** via a wired or wireless (e.g., Bluetooth) connection. The controller **504** may include one or more of various types of processors, CPUs, image signal processors (ISPs), graphics processing units (GPUs), coder/decoders (codecs), memory, and/or other components. The controller **504** may, for example, generate virtual content for projection by the light engine(s) **508**. The controller **504** may also direct operation of the light engine(s) **508**, in some embodiments based at least in part on input from a gaze tracking **520** component(s) of the headset. The gaze tracking **520** component(s) may be implemented according to any of a variety of gaze tracking technologies, and may provide gaze tracking input to the controller **504** so that projection by the light engine(s) **508** can be adjusted according to current position of the subject's eye(s) **590**. For example, different ones of the light sources **510** and projectors **512** may be activated to project light onto different eye box **560** points based on the current position of the subject's eyes.

In some embodiments, the holographic combiner **550** may be recorded with a series of point to point holograms; one projection point interacts with multiple holograms to project light onto multiple eye box **560** points. In some embodiments, the holograms are arranged so that neighboring eye box **560** points are illuminated from different projectors **512**. In some embodiments, the holographic combiner **550** and projectors **512** of light engine **508** may be arranged to separately project light fields with different fields of view and resolution that optimize performance, system complexity and efficiency, so as to match the visual acuity of the eye.

In some embodiments, the light engine **508** may include multiple independent light sources **510** (e.g., laser diodes, LEDs, etc.) that may emit light beams, under control of the controller **504**, that are independently projected by respective projectors **512**. As shown in this example, in some embodiments, there may be three light sources **510**A-**510**C coupled to three projectors **512**A-**512**C by three fiber-optic cables **514**A-**514**C; however, there may be more or fewer light sources, projectors, and connecting cables in some embodiments. In some embodiments, the projectors **512** may each include a two-axis scanning mirror (e.g., a MEMS mirror) that scans the light beam from a respective light source **510** to the holographic combiner **550**. The light sources **510** may be appropriately modulated (e.g., by controller **504**) to generate a desired image. In some embodiments, only one light source **510** and projector **512** (per eye) is active at a given time; when activated, a projector **512** projects light from a corresponding light source **510** (e.g., an RGB laser) to all of its eye box **560** points. However, in some embodiments, more than one light source **510** and projector **512**, or all of the light sources **510** and projectors **512**, may be active at the same time.

In some embodiments, each projector **512** may include optical elements that focus the light beam before scanning such that, once reflected off the holographic combiner **550**, the light is substantially collimated when it enters the subject's eye **590**. In some embodiments, each projector **512** may also include an active focusing element that may, for example, be used to change focus of the light beam as the light beam is scanned across a slow (horizontal) axis by the scanning mirror. Active focusing may also enable beams that diverge into the eye to, rather than being collimated, match the beam divergence of the supposed depth of the virtual object(s) being projected.

With the methods and components described above, the MR system **500** may not require extra moving parts or mechanically active elements to compensate for the eye **590** changing position in the eye box **560** or for the changing optical power from the holographic combiner **550** during the scan, which greatly simplifies the system architecture when compared to other direct retinal projector systems. Table 1 lists some example values for parameters of an example MR system **500** as illustrated in FIGS. **5** and **6**, and is not intended to be limiting.

TABLE 1

Parameter	Performance
Resolution	18 PPD
Frame rate	60 Hz
FOV at eye	61° × 54°
Eye-box size	13 mm × 9 mm
Object focus	0.2 m to infinity

The architecture, components, and operation of an example MR system **500** as broadly illustrated in and described for FIGS. **5** and **6** are discussed below in greater detail in reference to FIGS. **7** through **11**.

FIG. **7** illustrates components of a projector **512** in an MR system as illustrated in FIGS. **5** and **6**, according to some embodiments. Projector **512** may include a ferrule **716** via which a fiber optic cable **514** from a light source **510** (e.g., an RGB laser light source) is connected to the projector **512** unit. In some embodiments, projector **512** may include collimating and focusing optics **720** that focus the light beam **718** emitted by the light source **510** such that, once reflected by the holographic combiner **550**, the light beam **518** is substantially collimated when it enters the subject's eye **590**. Optics **720** may, for example, include one or more refractive lenses. In some embodiments, each projector may include a two-axis scanning mirror (e.g., a microelectromechanical systems (MEMS) mirror) that scans the focused light beam **718** to the holographic combiner **550**. In some embodiments, projector **512** may include a neutral density filter and plane mirror **730** that reflects the light beam **718** after focusing by optics **720** towards the scanning mirror **750**. In some embodiments, projector **512** may include an active focusing element **740** located between optics **720** and scanning mirror **750** that may, for example, be used to change focus of the light beam **718** as the light beam **718** is scanned across a slow (horizontal) axis by the scanning mirror **750**. This may also enable beams that diverge into the eye to, rather than being collimated, match the beam divergence of the supposed depth of the virtual object(s) being projected by the light engine **508**.

FIG. **8** illustrates an MR system that includes a headset with projectors and a separate control box containing light sources, according to some embodiments. MR system **500** may use reflective holographic combiners **550** to direct light projected by multiple projectors **512** into a subject's eyes, while also transmitting light from the environment to the subject's eyes. In some embodiments, the MR system **500** may include a headset (e.g., a helmet, goggles, or glasses as shown in FIG. **8**) that includes a frame **501**, multiple projectors **512**, gaze tracker(s) **520**, and lenses that include the holographic combiners **550**, for example implemented as one or more layers of holographic film on either side of, or embedded in, the lenses. The lenses may be curved glass or plastic with optical power depending on the user's particular requirements, or alternatively curved glass or plastic with no optical power. In this example embodiment, the system **500** includes three projectors **512** for each eye (projectors **512**A-**512**C for the right eye, and projectors **512**D-**512**F for the right eye), a gaze tracker **520** for each eye (gaze tracker **520**A for the right eye, and gaze tracker **520**B for the left eye), and a lens with holographic combiner **550** for each eye.

In some embodiments, the MR system **500** may also include a separate control box **502** that includes three light sources **510** for each eye (projectors **510**A-**510**C for the right eye, and projectors **510**D-**510**F for the right eye), and a controller **504** and power supply **506** for the MR system **500**. The light sources **510** may, for example, be RGB lasers. The control box **502** may, for example, be worn on the user's hip, or otherwise carried or worn by the user. The light sources **510** may be coupled to the projectors **512** by fiber optic cables **514**, with each light source **510** coupled to a respective projector **512**. In some embodiments, the control box **502** may include separate sets of light sources **510** for each eye **590**, with the light sources **510** for each eye connected to the projectors **512** on respective sides of the frame **501** by the fiber optic cables **514**. The light sources **510**, fiber optic cables **514**, and projectors **512** for a given eye **590** may be referred to as a light engine **508** for that eye **590**. Thus, the system **500** may include two light engines **508**, with one for each eye **590**.

The controller **504** may control operation of the light engine(s) **508**. The controller **504** may be integrated in the control box **502**, or alternatively may be implemented at least in part by a device (e.g., a personal computer, laptop or notebook computer, smartphone, pad or tablet device, game controller, etc.) coupled to the control box **502** via a wired or wireless (e.g., Bluetooth) connection. The controller **504** may include one or more of various types of processors, CPUs, image signal processors (ISPs), graphics processing units (GPUs), coder/decoders (codecs), memory, and/or other components. The controller **504** may, for example, generate virtual content for projection by the light engine(s) **508**. The controller **504** may also direct operation of the light engine(s) **508**, in some embodiments based at least in part on input from gaze tracking **520** component(s) of the headset. The gaze tracking **520** component(s) may be implemented according to any of a variety of gaze tracking technologies, and may provide gaze tracking input to the controller **504** so that projection by the light engine(s) **508** can be adjusted according to current position of the subject's eyes **590**. For example, different ones of the light sources **510** and projectors **512** may be activated to project light onto different eye box **560** points based on the current position of the subject's eyes **590**.

In some embodiments, the holographic combiners **550** may be recorded with a series of point to point holograms; one projection point interacts with multiple holograms to project light onto multiple eye box **560** points. In some embodiments, the holograms are arranged so that neighboring eye box **560** points are illuminated from different projectors **512**. In some embodiments, the holographic combiners **550** and projectors **512** may be arranged to separately project light fields with different fields of view and resolution that optimize performance, system complexity and efficiency, so as to match the visual acuity of the eye. In some embodiments, the projectors **512** may each include a two-axis scanning mirror (e.g., a MEMS mirror) that scans the light beam from a respective light source **510** to a respective holographic combiner **550**. The light sources **510** may be appropriately modulated (e.g., by controller **504**) to generate a desired image. In some embodiments, only one light source **510** and projector **512** (per eye) is active at a given time; when activated, a projector **512** projects light from a corresponding light source **510** (e.g., an RGB laser) to all of its eye box **560** points. However, in some embodiments, more than one light source **510** and projector **512**, or all of the light sources **510** and projectors **512**, may be active at the same time.

In some embodiments, each projector **512** may include optical elements that focus the light beam before scanning such that, once reflected off the holographic combiner **550**, the light is substantially collimated when it enters the subject's eye **590**. In some embodiments, each projector **512** may also include an active focusing element that may, for example, be used to change focus of the light beam as the light beam is scanned across a slow (horizontal) axis by the scanning mirror. Active focusing may also enable beams that diverge into the eye to, rather than being collimated, match the beam divergence of the supposed depth of the virtual object(s) being projected.

FIG. **9** illustrates an example eye box **560** of an MR system, according to some embodiments. As shown in FIG. **9**, in this example, there may be 27 eye box points **562** arranged in five horizontal rows that are spaced to form a hexagonal pattern, with five eye box points **562** in the first, third, and fifth rows, and seven eye box points **562** in the second and fourth rows. There are seven eye box points **562** for projector **512**A, ten for projector **512**B, and ten for projector **512**C. Pitch between neighboring eye box points **562** is approximately 2.6 mm. Eye box points **562** of the three projectors **512**A, **512**B, and **512**C are positioned in the rows such that pitch between any two eye box points **562** of a given projector **512** is approximately 4.5 mm. The large circle represents position and size of the subject's pupil. The MR system may use the gaze tracking component to detect position (and size) of the pupil, and use that information to select a suitable projector **512** to activate, while deactivating the other projectors **512**. In this example, the pupil is substantially centered on eye box point **562**A of projector **512**A, so projector **512**A is activated. Note that all of projector **512**A's eye box points **562** are illuminated when projector **512**A is active. The subject's pupil should be in the plane of the eye box **560**. The different eye box points **562** may, for example, compensate for differences in interpupillary distances (IPDs) between subjects, and for eye movements or rotations that place different points **562** in the subject's pupil.

In FIG. **9**, the large circle represents the largest pupil diameter (@5.3 mm) that can be accommodated by the example eye box **560** in a worst case scenario when the subject's pupil is pointed at a center point between three eye box points. In this case, any of the projectors **512** are equally suitable to project, while the other two projectors **512** are turned off. In this example, projector **512**A is activated, while projectors **512**B and **512**C are off, so the subject's pupil is receiving light from eye box point **562**A. Note that, if the subject's pupil gets any larger, light from neighboring projector **512**A eye box point **562**B may enter the subject's pupil. In some embodiments, to accommodate a range of possible user interpupillary distances (IPDs) and pupil diameters, holographic combiners may be provided with holograms that are tailored for particular users or for particular ranges, for example to provide additional spacing between neighboring eye box points **562** for users with larger maximum pupil diameters. Alternatively, in some embodiments, additional projectors **512** (e.g., four, five, or six projectors **512**) may be used so that the eye box points **562** for a given projector **512** can be spaced farther apart.

Non-Linear Slow Axis Scan

In some embodiments, instead of performing a linear slow-axis scan to the subject's eye, the scanning mirrors of projectors **512** may be configured or programmed to perform a non-linear slow axis scan. FIGS. **10**A and **10**B illustrate linear and non-linear slow axis scans in an MR system, according to some embodiments. FIG. **10**A illustrates a slow axis scan performed by a scanning mirror of one of the projectors **512** to holograms on a holographic combiner **550** from a projection point **1000** corresponding to the projector **512**. FIG. **10**B illustrates the distribution and resolution of pixels into the subject's eye for a linear slow axis scan (the dotted curve) compared to the resolution of pixels into the subject's eye for a non-linear slow axis scan (the dashed curve). As can be seen in FIGS. **10**A and **10**B, using a linear slow-axis scan results in a non-linear distribution of pixels into the eye box.

A reason for performing a non-linear scan is the number of available pixels. To more optimally distribute the available pixels to the subject's eye, a non-linear scan may be used to foveate the image so that more pixels are used near the center of the image where the subject's eye resolution is highest than are used in the peripheral regions of the image. Another reason for performing a non-linear scan is the trigonometry of the MR system; as can be seen in FIG. **10**A, each projector **512** project from a point **1000** off to the side of the holographic combiner **550** at a relatively shallow angle to the combiner **550**. Roughly half of the projector scan angle (from extreme **1012**A to center **1014**), corresponds to roughly a third of the field of view (FOV) into the eye box point **1010**. If the pixels were spread evenly across the projector scan, the resolution into the subject's eye would decrease from extreme **1012**A to extreme **1012**B according to the dotted curve in FIG. **10**B. The dashed curve in FIG. **10**B represents the target foveated resolution across the FOV.

The optimal non-linear slow axis scan may be different at different eye box position. Thus, in some embodiments, the scanning mirrors may be programmed with multiple (e.g., **5**) non-linear slow axis scans that can be applied at different eye box points.

Alternative Embodiments

In some embodiments, instead of the light sources being located in a control box and coupled to the projectors via fiber optic cables as illustrated in FIG. **5**, the light sources may instead be coupled directly to the projectors in an on-frame unit. FIG. **11** illustrates an embodiment of an MR system in which the projectors and light sources are contained in an on-frame unit. In these embodiments, the MR system **1300** may include a headset (e.g., a helmet, goggles, or glasses) that includes a frame **1301**, an on-frame unit including multiple light sources **1310** (three, in this example) coupled to projectors **1312** (three, in this example), a gaze tracking component (gaze tracker **1320**), and a lens that includes a holographic combiner **1350**, for example implemented as one or more layers of holographic film on either side of, or embedded in, the lens. The lens may be a piece of curved glass or plastic with optical power depending on the user's particular requirements, or alternatively a piece of curved glass or plastic with no optical power. Note that, for simplicity, the system **1300** is shown for only one eye; generally but not necessarily, there will be light sources **1310**, projectors **1312**, a gaze tracker **1320**, and a lens with holographic combiner **1350** for the second eye. The on-frame unit **1302** may also include a controller **1304** and a power supply (not shown). Alternatively, the controller **1304** and/or power supply may be implemented in a separate unit or device that is coupled to the on-frame unit via a physical cable and/or a wireless connection.

In some embodiments, the system **1300** may include multiple independent light sources **1310** (e.g., laser diodes, LEDs, etc.) that may emit light beams, under control of the controller **1304**, that are independently projected by respective projectors **1312**. As shown in this example, in some embodiments, there may be three light sources **1310**A-**1310**C coupled to three projectors **1312**A-**1312**C; however, there may be more or fewer light sources and projectors in some embodiments. FIG. **7** shows an example projector that may be used as projectors **1312**A-**1312**C. In some embodiments, each projector **1312** may scan a light beam from a respective light source **1310** to the holographic combiner **1350**. The light sources **1310** may be appropriately modulated (e.g., by controller **1304**) to generate a desired image. In some embodiments, only one light source **1310** and projector **1312** (per eye) is active at a given time; when activated, a projector **1312** projects light from a corresponding light source **1310** (e.g., an RGB laser) to all of its eye box **1360** points. However, in some embodiments, more than one light source **1310** and projector **1312**, or all of the light sources **1310** and projectors **1312**, may be active at the same time.

FIG. **12** illustrates a light engine in an MR system that uses a single scanning mirror and waveguides to direct light from multiple independent light sources to focusing elements that provide different projection points to a reflective holographic combiner, according to some embodiments. FIG. **13** further illustrates components of a light engine as illustrated in FIG. **12**, according to some embodiments. MR system **1400** may include a headset (e.g., a helmet, goggles, or glasses) that includes a frame **1401**, an on-frame light engine **1408**, a gaze tracking component (gaze tracker **1420**), and a lens that includes a holographic combiner **1450**, for example implemented as one or more layers of holographic film on either side of, or embedded in, the lens.

Light engine **1408** may include three light sources **1410**A-**1410**C (e.g., RGB lasers), a single two-axis scanning mirror **1412** (e.g., a MEMS mirror), and three fixed mirrors **1414**A-**1414**C that reflect scanned light from scanning mirror **1412** to entrance points on respective pupil-expanding optical waveguides **1416**A-**1416**C. Light engine **1408** may also include one or more mirrors **1411** for each light source **1410** (mirrors **1411**C**1** and **1411**C**2** for light source **1410**C are shown) that direct the light beam emitted by the respective light source **1410** to an entrance window of scanning mirror **1412**. The scanned light from scanning mirror **1412** is reflected by fixed mirrors **1414**A-**1414**C, enters respective waveguides **1416**A-**1416**C at entrance points, and exits the waveguides **1416**A-**1416**C at exit points corresponding to respective focusing components **1418**A-**1418**C that focus and/or collimate the light beam projected to the holographic combiner **1450**. In some embodiments, the entrance and exit points may be implemented as holograms using a holographic film. Alternatively, the entrance and exit points may be implemented as surface relief gratings (SRG), which are typically created using lithographic techniques rather than a holographic film. As shown in FIG. **12**, each focusing component **1418** may include an active focusing element **1440** that may, for example, be used to change focus of the light beam as the light beam is scanned across a slow (horizontal) axis by the scanning mirror, and may also include fixed focusing optics **1442**.

Scanning Mirror Embodiments

Embodiments of MR systems as illustrated in FIGS. **5** through **13** may use two-axis scanning mirrors, for example MEMS mirrors, to scan modulated light beams emitted by light sources (e.g., RGB lasers). In embodiments, the scanning mirrors may be configured to perform a slow scan on the horizontal axis, and a fast scan on the vertical axis. In some embodiments, the scanning mirrors may use electromagnetic (EM) actuation technology. However, other actuation technologies, for example electrostatic or piezoelectric actuation technologies, may be used in some embodiments. These other actuation technologies may, for example, reduce power consumption when compared to EM actuation technologies.

FIGS. **14**A and **14**B illustrate using resonance techniques on both axes of a scanning mirror, according to some embodiments. In some embodiments, the two-axis scanning mirrors may be configured to scan using a Lissajous curve or pattern in which both axes are resonant, but one axis (e.g., the vertical axis) is faster than the other axis. A Lissajous curve is the graph of a system of parametric equations which describe complex harmonic motion. FIG. **14**A illustrates a relatively simple Lissajous pattern. FIG. **14**B illustrates an example Lissajous pattern that may be used in some embodiments. As mentioned above in reference to FIGS. **10**A and **10**B, a non-linear scan is desirable due to the trigonometry of the MR system and the need to foveate the image so that more pixels are used near the center of the image where the subject's eye resolution is highest. In some embodiments, a Lissajous scanning pattern similar to the pattern shown in FIG. **14**B may be generated by software that encodes a system of parametric equations to provide a foveated distribution of pixels to the subject's eyes.

The methods described herein may be implemented in software, hardware, or a combination thereof, in different embodiments. In addition, the order of the blocks of the methods may be changed, and various elements may be added, reordered, combined, omitted, modified, etc. Various modifications and changes may be made as would be obvious to a person skilled in the art having the benefit of this disclosure. The various embodiments described herein are meant to be illustrative and not limiting. Many variations, modifications, additions, and improvements are possible. Accordingly, plural instances may be provided for components described herein as a single instance. Boundaries between various components, operations and data stores are somewhat arbitrary, and particular operations are illustrated in the context of specific illustrative configurations. Other allocations of functionality are envisioned and may fall within the scope of claims that follow. Finally, structures and functionality presented as discrete components in the example configurations may be implemented as a combined structure or component. These and other variations, modifications, additions, and improvements may fall within the scope of embodiments as defined in the claims that follow.

What is claimed is:

1. A system, comprising:

a controller;

a reflective holographic combiner comprising a plurality of point-to-point holograms;

a plurality of light sources that emit light beams under control of the controller; and

a plurality of projectors, wherein each one of the plurality of projectors includes a respective scanning mirror corresponding to a different one of the plurality of light sources, and wherein the respective scanning mirror of the each one projector scans a light beam emitted by the corresponding different light source to the holographic combiner;

wherein the plurality of point-to-point holograms redirect light beams received from the plurality of projectors to a plurality of eye box points, wherein each projector scans the light beam to two or more of the plurality of holograms, wherein the two or more holograms redirect the light beam to illuminate two or more respective eye box points, wherein neighboring eye box points are illuminated by different ones of the projectors.

2. The system as recited in claim **1**, wherein the light sources are RGB lasers.

3. The system as recited in claim **1**, wherein the scanning mirror of each projector includes a two-axis scanning mirror that scans the light beam emitted by the corresponding different light source to the holographic combiner.

4. The system as recited in claim **3**, wherein the scanning mirror is a 2D scanning microelectromechanical systems (MEMS) mirror.

5. The system as recited in claim **3**, wherein the scanning mirror performs a non-linear scan so that resolution is higher near a center of an image formed by the scan than in peripheral regions of the image.

6. The system as recited in claim **3**, wherein each projector further includes collimating and focusing optics that affect the light beam emitted by the respective light source so that the light beam is substantially collimated when reflected to the eye box points by the holographic combiner.

7. The system as recited in claim **3**, wherein each projector further includes an active focusing element that changes focus of the light beam as the light beam is scanned across a horizontal axis of the holographic combiner by the scanning mirror.

8. The system as recited in claim **1**, wherein the controller is configured to selectively activate particular ones of the plurality of light sources and respective ones of the plurality of projectors to scan light beams to the holographic combiner from different projection points corresponding to the projectors.

9. The system as recited in claim **1**, wherein the system further includes a gaze tracking component that tracks position of a subject's eye, wherein the controller selectively activates and modulates particular ones of the plurality of light sources to selectively illuminate particular ones of the plurality of eye box points based on current position of the subject's eye as determined by the gaze tracking component.

10. The system as recited in claim **1**, further comprising:

a headset configured to be worn on the head of a user, wherein the headset includes the reflective holographic combiner and the plurality of projectors; and

a control box separate from the headset, wherein the control box includes the plurality of light sources;

wherein the plurality of light sources are coupled to the plurality of projectors by fiber optic cables.

11. The system as recited in claim **10**, wherein the control box further includes the controller and a power source.

12. The system as recited in claim **1**, further comprising a headset configured to be worn on the head of a user, wherein the headset includes the reflective holographic combiner, the plurality of projectors, and the plurality of light sources.

13. The system as recited in claim **1**, wherein the system comprises a plurality of light sources, a plurality of projectors, and a holographic combiner for each of a subject's eyes, wherein the light sources, projectors, and holographic combiner for a given eye project light to an eyebox corresponding to that eye.

14. The system as recited in claim **1**, wherein the holographic combiner is one or more layers of holographic film on either side of or embedded in a lens positioned in front of a subject's eye.

15. A method, comprising:

emitting, by a plurality of light sources, light beams to a plurality of projectors under control of a controller, each light source corresponding to a different one of the plurality of projectors;

scanning, by the plurality of projectors, the light beams to a holographic combiner, wherein each one of the plurality of projectors includes a respective scanning mirror which scans the light beam emitted by the corresponding different one of the plurality of light sources; and redirecting, by a plurality of point-to-point holograms of the holographic combiner, the light beams to respective ones of a plurality of eye box points;

wherein each projector scans a light beam to two or more of the plurality of holograms, wherein the two or more holograms redirect the light beam to illuminate two or more respective eye box points, and wherein neighboring eye box points are illuminated by different ones of the projectors.

16. The method as recited in claim **15**, wherein the light sources are RGB lasers.

17. The method as recited in claim **15**, wherein each projector includes:

collimating and focusing optics that affect the light beam emitted by the respective light source so that the light beam is substantially collimated when reflected to the eye box points by the holographic combiner;

a two-axis scanning mirror that scans the light beam emitted by the respective light source to the holographic combiner; and

an active focusing element that changes focus of the light beam as the light beam is scanned across a horizontal axis of the holographic combiner by the scanning mirror.

18. The method as recited in claim **15**, wherein scanning comprises performing a non-linear scan so that resolution is higher near a center of an image formed by the scan than in peripheral regions of the image.

19. The method as recited in claim **15**, further comprising selectively activating particular ones of the plurality of light sources and respective ones of the plurality of projectors to scan light beams to the holographic combiner from different projection points corresponding to the projectors.

20. The method as recited in claim **15**, further comprising selectively activating and modulating particular ones of the plurality of light sources to selectively illuminate particular ones of the plurality of eye box points based on current position of the subject's eye.

21. The method as recited in claim **15**, wherein the reflective holographic combiner and the plurality of projectors are components of a headset configured to be worn on the head of a user, wherein the plurality of light sources are contained in a control box separate from the headset, and wherein the plurality of light sources are coupled to the plurality of projectors by fiber optic cables.

22. The method as recited in claim **15**, wherein the reflective holographic combiner, the plurality of projectors, and the plurality of light sources are components of a headset configured to be worn on the head of a user.

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